THE SUMMIT PLATES IN BLASTOIDS, CRINOIDS, AND CYSTIDS, AND THEIR MORPHOLOGICAL RELATIONS.

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Messrs. Robert Etheridge Jun. and Dr. P. Herbert Carpenter, have recently published, under the auspices of the Trustees of the British Museum, a most important and valuable contribution to palaeontological research, in the form of a memoir, which is in effect a Monograph of the British Blastoids.* The work is marked by a thoroughness and wealth of illustration, characteristic of the scientific publications on special subjects issued under the patronage of the British Goverment, which makes us wish that the facilities offered by our own government in that direction might be a little more extensive. The high reputation of the authors is such an ample guarantee of scientific excellence in the execution of the work, that it is scarcely necessary to do more than allude to the fact of its appearence. The points as to which we should venture to differ with the authors are but few; upon these, however, we regret we find ourselves materially at variance with their views.

The whole of chapter IV,-from p. 66 to 74 inclusive, is devoted to a discussion of the summit plates and their morphological relations. The authors undertake to prove that while the summit plates in the Blastoids do not present, as a rule, any very definite arrangement (p. 118), yet they exhibit a series of variations in number and position, in some degree corresponding with a similar but more extensive series of variations among the Palaeocrinoidea; that both exhibit a transition from five closely united plates fully covering the summit, to a set of six proximal plates surrounding a central one. The six proximal plates are held by them to be the homologues of the five oral plates of the Neocrinoidea—a theory to which the division of the proximals into six or more has always interposed a very serious difficulty. If such a transition from five closely fitted plates to six or more around another could be established, of course its tendency would be to diminish the diffi-

*Catalogue of the Blastoidea in the Geological Department of the British Museum (Natural History), with an Account of the Morphology and Systematic Position of the Group, and a Revision of the Genera and Species, By Robert Etheridge Jun. and P. Herbert Carpenter, D. Sc., F. R. S., P. L. S.-4 to.-Pp. I-XVI, 1-322; 20 plates. London. Printed by order of the Trustees, 1886.

culty; but it remains to be seen how far the authors have succeeded in proving it.

A covering of the summit openings in various genera has been described by several writers. This has been generally considered as representing the same structure in all these genera; whereas there is to be found among the coverings, thus described, two distinct structures, which are totally different from each other, and are characteristic, so far as observed, of distinct groups of the Blastoidea.

The first of these of which any detailed account has been attempted, was observed by Roemer in 1851, in *Elaeacrinus Verneuili*,* which he described as having the summit plates closed by a hexagonal central plate, surrounded by six others, four of equal size and two smaller. Shortly afterwards Shumard,[1] in describing his new species *Pentremites Sayi*, stated that "the central opening is closed by minute, usually pentagonal and hexagonal plates, arranged in a manner somewhat similar to those of *Pentremites* (*Elaeacrinus*) *Verneuili*," and he added in a note:—"the same structure occurs in *Pentremites Norwoodi* and *P. melo* Owen and Shumard, of which I have fully satisfied myself from an attentive examination of many specimens."

In 1863, Dr. White, in a paper on the summit structure of *Pentremites*,[2] confirmed the observations of Shumard as to *Pentremites Norwoodi*, and stated that in this species the whole central space between the summit tubes and the anal aperture "is overlaid with an integument of microscopic plates, entirely covering the central aperture, passing out between the bases of the tubes in a double series of plates, and was evidently continued far down the central grooves of the pseudambulacral fields." He also discovered in *P. stelliformis*[3] a covering of the central summit aperture "essentially the same as in *P. Norwoodii*," and he described it as consisting of "five small plates, arranged like a five pointed star, with the points touching each of the upper ends of the interradial plates, thus completely covering the summit aperture."

Figures of the summit plates of *Granatocrinus Norwoodi* and *Orophocrinus* (*Codonites*) *stelliformis* were subsequently published by Meek and Worthen,[4] confirming the observations of Shumard and

*Archiv f. Naturgesch., 1851. Jahrg. XVII, p. 378.

[1] Palaeontology, in Swallow's Geol. Surv. Mo. 1855, p. 186.

[2] Bost. Journ. Nat. Hist. 1863, Vol. VII, No. 4, p. 484.

[3] Ibid. p. 487.

[4] Illinois Geol. Rep., Vol. V. Pl. IV, figs. 2a, 5.

White; and we [5] in 1881 gave a figure of the summit covering in *Schizoblastus* (*Granatocrinus*) *Sayi.*

In 1858, Shumard [6] described what he took to be a somewhat similar covering in a specimen of *Pentremites conoideus*, which he figured and described as having the central stelliform space (mouth) "perfectly closed by six small, microscopic plates, a central one of a pentangular form surrounded by five smaller pentagonal pieces, which unite with the edges of the aperture and form a little dome. The five ovarial openings are each, in like manner, closed, as represented in the figure by six minute polygonal plates, so arranged as to form a little elevation." Shumard's description of *P. conoideus* was endorsed by Billings[1] who copied his figure, but modified it by adding a small pore at each of the five angles, through which, as he thought, the ambulacra entered the interior.

The fact of the closure of the summit opening in the above mentioned species, and in *Pentremites* generally, has on the other hand been denied by Dr. Hambach,[2] who states that the central opening "was never closed by additional plates, as intimated by some authors (Billings and Shumard), although specimens are frequently found (and I have some in my collection) where it appears as if the summit were closed by additional plates, which, on close examination, however, prove to be Bryozoa or ovulum-like bodies." In a subsequent paper he [3] says that Shumard's original specimen of *P. Sayi*, which was figured in the Missouri Report, "proves to have only a covering of minute calc-spar crystals on the summit, leavings of the surrounding matrix, which could easily be removed by applying a moist camel's hair brush to them;" and he adds—"my specimens which show such a covering * * * prove that the covering consists only of fragments of broken up pinnulae which were washed into the ambulacral furrows and remained there."

As to Hambach's general statement that the central opening was never closed by additional plates, he has undoubtedly been misled by the condition of his specimens. We are certain that if he were to examine the numerous specimens in our collection of *Schizoblastus Sayi, Granatocrinus Norwoodi, G. melo, Orophocrinus stelliformis,*

[5] Revision of the Palaeocrinoidea Pt. II, Pl. XIX, fig. 3.

[6] Trans. St. Louis, Acad. Sci. 1858, Vol, I No. 2, p. 243.

[1] Amer. Journ. Sci. 1869, Vol. XLVIII, p. 82.

[2] Trans. St. Louis, Acad, Sci., 1880, Vol. IV, p. 150.

[3] Trans. St. Louis, Acad., Sci., 1884, Vol. IV No. 3, p. 540.

O. conicus, O. fusiformis, an undescribed *Mesoblastus* from New Mexico—to say nothing of *Elaeacrinus* from various localities, and of three different species—all having the central opening perfectly closed by plates, he would come to a different conclusion. We have found *Schizoblastus Sayi* in especially good preservation, with summit plates firmly attached and unincumbered by deposition of fragments of any kind. It is by no means rare to find specimens of this species, in which the summit plates and portions of the covering pieces are in place. They may be seen in several collections in Burlington, and these parts may be vigorously brushed with the stiffest bristles with entire safety. The same may be said of all the above named species, and there can be no sort of question that a plated covering does actually exist in all of them.

With regard to the type specimen of *Pentremites conoideus,* however, we are fully convinced that Hambach is right, and that his definition of the so called plates described and figured by Shumard as covering the center and ovarial openings, as "ovulum–like bodies," for which he was somewhat sharply ridiculed by Dr Carpenter [1] is a perfectly correct statement. The species occurs abundantly at Spurgen Hill, Ind. in a friable, light-colored oolitic limestone, which is composed almost entirely of minute organisms, small bivalves, Gasteropods, etc., and these are interspersed profusely with small egg-shaped bodies of almost uniform size. Nearly every specimen of *Pentremites* from that locality has some of these bodies exposed at the openings, but we find nowhere any regularity in their arrangement, and they are seen equally plain in much worn and weathered specimens.

Prompted by a strong desire to examine Shumard's type, the specimen from which his figure was made, we applied to Dr. Hambach for the loan of it from the Museum of the Washington University at St. Louis, and he forwarded it to us with a promptitude and courtesy, for which he has our warmest thanks. The specimen is very interesting, and shows clearly that Shumard's figure is a fiction The center appears to be closed, and also the spiracles, not by plates, but by foreign particles such as we have described above. The specimen has the appearance of considerable weathering; none of the outlines are sharp, and the spiracles, which in good specimens are markedly angular, are here almost round. In one of the spiracles only, the arrangement of the particles appears somewhat like

[1] Ann. and Mag. Nat. Hist., Ser. 5, Vol. VIII., 1881, p. 422.

Shumard's figure. At a hasty glance there seem to be six pieces, a central one surrounded by five others; but when examined under a strong magnifier there appear two pieces in the center, and six surrounding them. From this one spiracle, the arrangement of the supposed plates in all the other openings was probably inferred, and the figure made accordingly; for the arrangement of the so-called plates at the four other openings is altogether different, and very irregular. So we find at the anal opening a good sized Gasteropod beside other pieces.

The central opening is covered by a single, comparatively large, elongate body, ovoid in form, which does not actually close the opening, but rests inside of it, beneath the level of the deltoids, slightly touching them. Its position is such that if it represented the summit structure, the food grooves could not have entered the peristome This is also one of those foreign bodies to which we alluded, but its surface is too much worn to say much about it.

Etheridge and Carpenter[1] express some doubt of the correctness of Shumard's description as to the plates covering the spiracles, although they take Hambach to task (pp. 68, 164) for disputing the same description as to the covering of the central opening. They allude, however, to White's discovery of a plated integument over the anal opening in *Orophocrinus stelliformis*, which we are able to confirm. This covering we have found well preserved, not only in *O. stelliformis*, but also in two new species which we described for Vol. VIII. of the Illinois Report now in preparation. In all cases where we found this structure intact, it lies below the level of the deltoid through which the aperture penetrates, and is composed of a large number of small, irregular pieces without any visible opening.

We do not mean to say that the peristome and spiracles were not covered by plates in *P. conoideus*, but we do assert that there was no *such* covering as figured by Shumard. Even in the shape of the spiracles his figure is totally erroneous. He represents them as very regularly pentangular, so as to receive the five supposed plates neatly filling the angles, and as surrounding a central one, one of their sides facing the central opening instead of an angle. The fact is, however, the spiracles are not pentangular but quadrangular, somewhat unequally diamond-shaped with sides slightly curving, the outer angle obtuse, conforming to, and in fact formed by, the slope of the side

[1] Catalogue of the Blastoidea, p. 69

pieces of adjacent ambulacra. The opposite angle toward the centre is acute, and is occupied by a shallow groove which projects in form of a lip toward the center. This form of the opening is remarkably constant in all the specimens of this species, and is characteristic not only of the genus *Pentremites* but also of *Pentremitidea*. That in *Pentremites* a considerable portion of the spiracles was closed by plates of some kind, we think quite probable, but the structure was certainly very different from that described by Shumard.

In 1850, Owen and Shumard [1] discovered a peculiar summit structure in *Pentremites* in a specimen of *P. Godoni*, which they described as a "conical covering of small plates." In 1858 Shumard [2] observed a similar structure in *P. sulcatus*, of which he gave the following account. "In this fossil there rises from the center of the summit a little pyramid with five salient and five retreating angles, the salient angles being directly opposite the extremities of the interradial pieces, while the retreating angles correspond to the center of the pseudo-ambulacral fields. The base of this little pyramid is joined to the superior edges of the pseudo-ambulacral fields so as to completely roof in the buccal and ovarial apertures. It consists of about fifty pieces, arranged in ten series; the first or exterior ones in each series being of a triangular form, the others elongated quadrilateral. Two series of pieces stand over each ovarial aperture, those of one side uniting with their fellows of the opposite side at the salient angles of the pyramid."

No further attention was paid to this structure until 1884, when Hambach [1] proposed to amend Shumard's description by adding that this cone-shaped body "consists of little tubes running parallel with each other and roofing in the summit of the calyx in a conical shape (but not the central opening.) They protude through the same apertures in which the hydrospires terminate; there are about five of these tubes to each aperture, which seem to correspond with the plicas of the hydrospiric sac." He concludes that these tubes extend down into the interior of the calyx, and he takes them "to be the ovarian tubes."

We can confirm Hambach's observation as to the existence of elongate pieces having the external appearance of tubes placed side by side, though we do not concur in his inference of a connection

[1] Journ. Acad. Nat. Sci. Phil., Vol. II. Pt. I, p. 65

[2] Trans. St. Louis Acad. Sci., Vol. I, No. 2, p. 244.

[1] Trans. St. Louis Acad.Sci. 1884,Vol. II, No. 3, p. 541

with his so-called "ovarian tubes," for we have been unable to find any evidence that they pass into the calyx, or that they are longitudinally perforate.

We have been so fortunate as to obtain a large series of specimens exhibiting the structure under consideration in more or less perfection in several species, and we are thereby enabled to present a somewhat fuller description of its nature. We have observed it in *P. sulcatus* in 2 specimens; *P. Godoni* in 2 specimens; *P. pyriformis* in 4 specimens; *P. elegans* in 19 specimens; *P. cervinus* in 3 specimens; and *P. abbreviatus* in 5 specimens, in all conditions of preservation.

It consists in most of them of ten series of pieces—that is five double series, going out in salient angles toward the extremities of the interradial pieces (deltoids)—while in other species the series seem to be composed of more than two rows, and they are not so regularly arranged as in species with only two series. The pieces are located at both sides of, and apparently within, the so called spiracles. They are, as clearly shown in perfect specimens, not plates but elongate, tapering spines, closely packed together, comparatively robust, with a more or less obtusely quadrangular and sometimes, perhaps triangular section, usually curving a little at the tips toward the center. They vary in length, the outer ones being the shortest, those toward the center the longest. We have been unable to discover anything like transverse sutures or longitudinal perforations, and they probably consist of a single solid piece. Although limited to the spiracles, their tips are generally drawn together so as to form a kind of roof over the central opening, while if standing erect they would leave a space in the middle. The spines apparently have no connection whatever with the ambulacra; the side pieces run out and disappear at the spiracles, forming in fact their outer border, and only the food grooves pass in between them to the peristome. Whether the spines cover the spiracles directly, or rest upon independent plates, we cannot say positively, but we are inclined to think that the latter may be the case, and the plates bearing them are set in around the inner margin of the spiracles, so as to cover the greater part of the opening, leaving perhaps a shallow channel passing toward the center over the lip which we have described above.

That the spines, or plates bearing them, extended only over a part of the so-called spiracles, is strongly indicated by the condition of a very interesting specimen of the type of *Pentremites symmetricus* Hall, from Chester, Ill., in which it seems as if the whole pyra-

mid and the covering pieces along the ambulacra, at least near the mouth, were intact and in place when the animal was deposited. It is enveloped in a fine grained silicious mud, fine enough to pass through the smallest opening, and to leave a cast of all cavities. In this specimen there appears over the actinal center a small rounded knob, from which pass out radially, along the upper part of the food grooves, delicate string-like impressions of the inner part of the closed groove. From the inner angles of the spiracles, and passing over the lip-like projections at those angles, are small elevated rounded ridges connecting with the central knob, while the other portion of the spiracle is depressed sufficiently to receive a good sized set of plates. Considering that the parts composed of this fine mud are the counterparts of open spaces as they existed when the specimen was imbedded—all plates and spines being removed by disintegration after it weathered out of the matrix—we may infer that there was at the inner angle of the so-called spiracle a small channel or opening, which probably served as the true spiracle, while the remainder of the aperture—which in this view of the case would represent a mere break in the test—was all covered. At the posterior opening the mud mould occupies a larger space, indicating a larger opening; otherwise we are not able from our specimens to give any special account of the anal opening; neither can we observe any special difference in the arrangement of the spines about the posterior opening from that of the others.

The shape and construction of the spiracles in *Pentremitidea* is very similar to that of *Pentremites*, and we should not be surprised to find its summit surmounted by a similar structure. We fully agree with Etheridge and Carpenter in placing these two genera in the same family, but we are not so sure as to *Mesoblastus*, which we think might be placed more appropriately with *Schizoblastus* and *Cryptoblastus*.

The condition of the central opening in *Pentremites* cannot be accurately determined from any of our specimens, but we have distinctly seen that it is covered by several plates, independent of the roofing by spines.

The food grooves, which pass out between the spines at the retreating angles of the cone, are vaulted over by two rows of covering pieces which are alternately arranged. These pieces close the central groove of the ambulacrum, whence they branch off so as to cover also the lateral grooves toward the pinnules. The plates cov-

ering the side grooves, which are arranged as regularly as those of the main grooves, have been traced by us as far as the fifth side pieces, but may have extended farther down. In spite of their small size, the plates are very distinct in our specimens, those of the upper row resting closely against the spines.

Messrs. Etheridge and Carpenter have given two figures showing the summit of *Pentremites* in two different conditions of preservation, both of them from specimens belonging to us. The first figure of *P. sulcatus*, (Pl. I, fig. 8.), gives a somewhat incorrect impression of the external appearance of the pyramid, owing to the fact that the spines composing it have been irregularly broken off a little way above their bases, so that what there appear as plates are really the cross sections of the spines. The fracture, however, is not regular, nor at right angles to the long dimension of the spines, so that the figure does not correctly represent either the real form of the cross sections, or their relative positions. We may observe also that the figure does not give the central portions. By applying a little aniline coloring matter we have been able to see the sutures indicating the broken ends of spines, but the fracture is so irregular that the arrangement cannot be distinguished. In their other figure on Pl, V, fig, 28., which gives a good idea of the form and character of the spines composing the pyramid, some of the pinnules are preserved overlapping the spines and resting upon them, showing in marked contrast the difference between the two structures.

After quoting and commenting upon Shumard's and Hambach's descriptions of the pyramid in *P. sulcatus*, and having before them the original specimens represented in the above mentioned figures, Etheridge and Carpenter[1] give their intrepretation of the facts as follows:

"Mr. Wachsmuth has sent us a fine specimen, which may perhaps throw some light on this difficult question, (Pl, I, fig. 8.) The peristome and spiracles are almost completely covered by what seems to be the base of the little pyramid described by Shumard." The upper part of the pyramid described by Shumard and Hambach "seems to us to be constructed by the proximal pinnules, as in the specimen represented on Pl. V, fig. 28. In Mr. Wachsmuth's example of *P. sulcatus*, however, these proximal pinnules are not preserved, and the angles of the pyramid extend outwards towards the pointed ends of the visible parts of the deltoids. At two of these angles there seem to be indications of a double series of plates above

[1] Catalogue of the Blastoidea, p, 70.

the spiracles." They "have little doubt that this is fundamentally the same structure as was seen by both Shumard and Hambach." According to the latter author, there are "about five" of the supposed tubes to each spiracle; while Shumard says that two series of pieces stand over each opening, and except in the anal interradius this seems to be the condition of Mr. Wachsmuth's specimen also. But we do not think that the pieces have the tubular nature which Hambach assigns to them; for we doubt whether they are more than the proximal pinnules grouped around the peristome as shown in our Pl. V, fig. 28."

In their explanation of the plate, this figure is said to be a "radial view of a decorticated specimen, with the pinnules rising above into a kind of dome." No allusion is made to any difference between the bundles of jointed pinnules which fall over the summit from each side, and the set of apparently rigid, erect and jointless appendages which are seen between them. Nor do the authors anywhere in the text appear to recognize any such difference, although it is to us quite apparent, both in the figure and in the specimen which was before them.

After arriving at this as a probable interpretation of the structures observed by Shumard and Hambach and figured by themselves, and dissenting from Hambach's supposition, that the so-called tubes pass down into the interior of the calyx, they arrive at this further conclusion: "We are much more inclined to think that we have here to deal with an extension of the smaller system of summit plates, which occur in other Blastoids. In *Granatocrinus* and *Elaeacrinus* only the peristome appears to be covered, (Pl. VII, figs, 4. 11. 13; Pl. XVIII, fig. 16), except perhaps for the anal aperture in *G. Norwoodi;* while *Orophocrinus* and *Stephanocrinus* have a group of plates around the anal aperture (Pl. XIX, fig. 9). In *Pentremites conoideus* the other four spiracles are perhaps also closed by plates; and except in the larger size and abundance of the plates it is no great advance from this condition to that which we have seen in *Pentremites sulcatus* (Pl. I, fig. 8.), but we await further information."

The supposed closure of the spiracles by plates in *Pentremites conoideus* proves to be unsupported by the facts. A correct understanding of the nature of the pyramid surmounting the vault in *Pentremites sulcatus* and allied species will, we think, fully demonstrate that this structure, which probably existed in all *Pentremites*, is a totally different thing from the covering of the anus in *Oropho-*

crinus, Stephanocrinus or *Granatocrinus.* In the three latter types, the so-called covering does not extend to the spiracles, but consists apparently of a sort of moveable plates, by means of which in various ways the anal aperture could temporarily be opened or closed as its functions required.

The views expressed by Etheridge and Carpenter that these spine-like pieces forming the pyramid are nothing but the proximal pinnules, cannot, in our opinion, be sustained by any of the evidence. There are very serious objections to it:—

1. They consist of a single piece throughout their entire length, whereas pinnules are composed of small joints. The specimens all show this distinction well, and it may be clearly seen in Etheridge and Carpenter's Pl. V, fig. 28.
2. They have no ventral groove, and taper to a point; while pinnules are nearly uniform throughout, and especially do not taper perceptibly from their bases.
3. They are more robust than the pinnules in the same specimen, and shorter—the pinnules passing beyond their tips.
4. The best preserved specimens show that the pinnule sockets end at the spiracles where the two rows of adjoining ambulacra come together in a point. The spines, however, seem to begin where the pinnules end, and extend from there inward, the clusters widening toward the center so as to form the retreating angles at the base of the pyramid.
5. The spines are interradial and interambulacral, and as such may belong to an interambulacral system, which perhaps is unrepresented in other groups of the Blastoids, but certainly form no part of the ambulacral system.

Whatever the spines in *Pentremites* may be, or represent morphologically, we think it will have to be conceded that they are not "proximal pinnules," and not comparable to the plates covering the anus of *Orophocrinus, Stephanocrinus* or *Granatocrinus.*

On page 73, Messrs. Etheridge and Carpenter attempt to establish a series of variations in the summit plates of the Blastoids, "similar to that which can be traced among the Palaeocrinoids. The simplest form of summit which occurs in any Blastoid is that presented by *Stephanocrinus.* The peristome is completely closed by the five triangular plates of the so-called proboscis." They state that Hall, in his diagram of the structure of the summit in *Elaeacrinus elegans*[1]

[1] 15th. Rep. N. Y. St. Cab. Nat. Hist. 1862, p. 153.

figures only five plates of equal size; and they add:—"These five plates of *Stephanocrinus* and *Elaeacrinus* have exactly the same relation to the peristome and ambulacra as the oral plates of a Neocrinoid, and we do not see how their mutual homology can well be disputed." On page 74 they continue: "The difference between *Elaeacrinus elegans* or *Stephanocrinus* and *E. Verneuili*, as described by Roemer, is very much the same as that between *Culicocrinus* and the simplest form of *Platycrinus*. *Stephanocrinus*, like *Culicocrinus*, has but five plates in the vault; while in *E. Verneuili* there are at least seven, viz.: one orocentral, four proximals of equal size, and two smaller ones on the anal side." They allude to White's description of the summit of *Orophocrinus stelliformis* as consisting of five small plates etc., which they say is "just as in *Stephanocrinus* and in *Elaeacrinus elegans*"—though they add that their arrangement does not seem to be very constant. On page 75, they speak of the summit of *Granatocrinus Norwoodi* varying in a similar manner, and of a "somewhat less regular arrangement" in *Schizoblastus Sayi*.

It thus appears that their conclusion that the plates of the vault in Blastoids "rarely exhibit any definite arrangement,"(p. 118) and that there is a series of variations in the summit plates of the Blastoids similar to, and to some extent parallel with, those which they assume to exist in Palaeocrinoids, is based on the presence of five plates in *Stephanocrinus;* the assumption of five plates in *Elaeacrinus elegans* and *Orophocrinus stelliformis*, in contrast with seven plates in *E. Verneuili;* and variability in the number and arrangement of plates in the summit of *Granatocrinus Norwoodi* and *Schizoblastus Sayi*.

It is somewhat unfortunate for the validity of this speculation that *Stephanocrinus* cuts so important a figure in it, as it has since been discovered to be not a Blastoid at all, but a brachiate Crinoid; a fact,[1] it is proper to say, which is noticed by the authors in their preface. This genus, therefore, must be eliminated from among the premises on which the argument is built, and the "simplest form" must be looked for elsewhere. Let us see how far the others will stand the test of examination.

Elaeacrinus elegans was described by Hall[2] under *Nucleocrinus*, and in his specific description,—and not simply in his generic diag-

[1] Revision of the Palaeocrinoidea, Pt. III, p. 282, etc.

[2] 15th, Rep. N. Y. St. Cab. Nat. Hist. 1862 .p. 147.

nosis, as stated by Etheridge and Carpenter—he says the summit is "occupied by *five or more* small plates." In the diagram, on page 153 of the work cited, the summit is represented as divided into five equal and similar areas by the meeting of lines prolonged from the middle of the ambulacra. It is apparent that no attempt was made to give the exact form or number of those plates. They are not lettered as the other plates are, and no mention is made of them in the explanation of the figure; nor does Hall anywhere seem to have attached sufficient importance to the summit plates to give a description of their shape, position, arrangement, or relative size.

In order to satisfy ourselves as to what the real facts are, we applied to Prof. R. P. Whitfield for the loan of the type specimen of *E. elegans* showing the summit plates, now in the collection of the American Museum of Natural History in New York City. Prof. Whitfield, with his usual kindness, for which we are under renewed obligations to him, promptly sent us the original specimen from which fig. 14, of Pl. I, as well as the diagram on page 153 of the 15th Report was made; and in his letter transmitting it he says: "I fear you will not see clearly the arrangement of the plates. There are *more* than five plates—probably eight". The italics are his. By applying water, colored with aniline, and then moderately brushing the surface so as to remove the coloring matter except from the sutures, we were enabled to distinguish the presence of a central piece surrounded by seven others,—four large and uniform, and three smaller ones at the posterior side (fig. 11.) This gives a summit structure substantially the same as that of *Elaeacrinus Verneuili*, (see Etheridge and Carpenter, Blast. Cat. p. 215).

We also applied to Dr. Barris for the loan of his specimens of *Elaeacrinus obovatus*, and these, together with our own, gave us eight specimens of this species, all having the summit in *situ*. The four large proximals are readily recognized in most of them, but only a single specimen enabled us to distinguish all the plates as they are shown in fig. 12. In four others, the suture line between the central plate and the small anal piece is seen as plainly as we could wish, but there is no trace of a suture toward the smaller proximals (fig. 13); while in the three remaining ones, including the largest specimen, it appears as if the summit consisted of only five plates (fig. 14.) There is, however, no variation in the form and general outline of the summit in any of these specimens. The summit in all of them rests posteriorly between the two halves of the

compound deltoid and against the intermediate large anal plate, and in all of them the lower margin is perforated and occupied by one half of the anal aperture, thus showing that in this species also the summit consists primitively of eight pieces, of which the suture lines became partially obliterated.

In the type specimen of *Elaeacrinus meloniformis*, which Dr. Barris was kind enough to send us also, the arrangement of the summit plates is the same as in *E. obovatus*, and we clearly distinguished the small anal plate.

It thus appears that in the known species of *Elaeacrinus* the summit plates consist of a central plate surrounded by six or more proximals, and that in no case do they consist of five primitive plates; so that the "simplest form of summit"—five plates only—has not been found in *Elaeacrinus*. The assumed parallelism of differences between *E. elegans and E. Verneuili* among the Blastoids, and *Culicocrinus* and the simplest form of *Platycrinus* among the Crinoids, encounters a very serious interruption in consequence—unless, indeed, it should turn out that there is a parallelism in these cases of an altogether different character from that contemplated by the English authors.

The summit of *Orophocrinus stelliformis* was stated by White[1] to consist of "five small plates arranged like a five-pointed star, with the points touching each of the upper ends of the interradial plates." We do not doubt that Dr. White thought to observe such arrangement, but we think it very probable that the condition of his specimen was such that he overlooked the central plate, which may easily happen, as the sutures are often difficult to observe. In a large number of specimens we have never found a single one with the summit composed of five plates only, or with a central plate surrounded by five proximals. We found, however, that in specimens of this species, as well in *Granatocrinus Norwoodi* and *Schizoblastus Sayi*, when the covering plates are in place, they often partly overlap the summit plates, and in such cases the arrangement of the latter cannot be distinctly observed. When the covering pieces are absent, and the summit plates alone are intact, as in several of our specimens, the arrangement is quite regular. We have made a careful examination of a large series of specimens, not only of *O. stelliformis* but also of our new species *O. fusiformis* and *O. conicus*, in which the summit plates are more frequently preserved. In all of them there is a

[1] Boston Journ. Nat. Hist. 1863, Vol. VIII, No. 4, p. 487.

central plate, surrounded by others, either six or seven. Even the original of Etheridge and Carpenter's figures 11 and 12 on Pl. XV, in our collection, upon the application of coloring matter to bring out the sutures, proves to have a quite regular arrangement of the summit plates, which the artist who drew the figures failed to detect. There are certainly not "five small plates," but a central plate surrounded by six proximals.

According to our observation, therefore, of the best preserved material known, the summit of *O. stelliformis* does not represent the "simplest form,"—"just as in *Stephanocrinus*."

There remains only to consider *Granatocrinus Norwoodi* and *Schizoblastus Sayi*, as to both of which we remark that there is often presented much apparent irregularity and variability in the arrangement of their summit plates. But we find that this is due to the encroachment of the covering plates, which sometimes largely overlap them, as is well shown by Ether. Carpenter's Pl. VII, figs. 11 and 13. But in natural internal casts, in which we have the impressions of the inner surface of the plates, they appear larger and much more regularly arranged. Among a large number of specimens we have failed to find a single example of a summit closed by only five plates; while in a large proportion of them we distinguished clearly a central plate surrounded by six or more proximals. Whatever variations, however, of form and arrangement of summit plates may be found to exist in these two species, we feel warranted in asserting that the "simplest form" is not one of them.

On page 71, (Catal. of the Blastoidea), Messrs. Etheridge and Carpenter say that "in 1877, Wachsmuth pointed out that a definite arrangement of plates is more or less traceable in the vault of many Palaeocrinoids. There is a single central plate, with five or, more frequently, six others disposed interradially round it." It would naturally be inferred from this remark and the context, not only that *five* proximals around a central plate is one recognized condition in the vault of many Palaeocrinoids, but also that Wachsmuth had so expressed himself:—whereas the fact is *he said nothing of the kind* in the paper cited, but on the contrary spoke only of "7 apical plates"—a central, four large, and two small ones; and this number, or a greater, has been insisted on by us as being the almost universal rule.

In seeking for a transition or variation in the summit plates of Palaeocrinoids, comparable to that which they assume to exist

among the Blastoids, they take the young stage of *Allagecrinus* (p. 72), as presenting "the simplest form of vault," i. e. five plates without any central; and *Haplocrinus* next, with a central piece and five proximals, "neither *Allagecrinus* nor *Haplocrinus* having any calyx interradials." *Culicocrinus* is cited as having five large summit plates resting on the calyx interradials, and without any central piece. Then come *Platycrinus* and the Actinocrinidae as exhibiting varying degrees of complexity, but having a central plate, which they call an "oro-central," surrounded by proximals. In this case also, they base a large part of their argument upon premises which are by no means universally recognized, or are free from dispute. We consider it far from being an established fact, that either *Allagecrinus* or *Haplocrinus*—*Culicocrinus* will be considered later on—are without calyx interradials.

As we have before stated, Etheridge and Carpenter maintain, and it has been steadily insisted on by Dr. Carpenter since 1879, that the proximal plates, surrounding the central plate in Palaeocrinoids, their so-called "orocentral," represent the five orals of Neocrinoidea. This involves the assumption of a homology between a set of plates covering the actinal center, which are five in all stages of the Neocrinoids in which they exist, and a set of plates which, when present in Palaeocrinoids consist of six or more plates, which do not cover the actinal center, but which enclose another structure that does. It is in order to get rid of some of these difficulties that the authors attach so great importance to the cases of *Allagecrinus, Haplocrinus, Culicocrinus, Coccocrinus,* and *Stephanocrinus,* in which they undertake to point out a series of five plates at the ventral side, as the representatives of six or more proximals in Palaeocrinoids generally, and which at the same time might be successfully homologized with the orals of the Neocrinoids. In this connection they remark on page 73:—

"Since the preceding paragraph was in type, we have received the latest publication of Messrs. Wachsmuth and Springer, according to whom the five plates which form the ventral pyramid of *Stephanocrinus* are 'calyx interradials,' and cannot therefore be homologous with the orals of a Neocrinoid. In making this comparison Messrs. Wachsmuth and Springer seem to have altogether overlooked the fact that *Stephanocrinus* has well developed calyx interradials, namely, the deltoids. * * * The American authors regard the deltoid pieces of the Blastoidea, and by implication

therefore those of *Stephanocrinus*, as homologous with the large calyx interradials of the Cyathocrinidae, a view in which we entirely concur, as we have explained on p. 10. But in applying this name to the five plates which form the ventral pyramid and cover the mouth of *Stephanocrinus*, and also of *Haplocrinus* and *Allagecrinus*, as they do in their latest publication, they seem to us to be going very much too far. We regard the five summit plates of all three genera as truly homologous with the orals of the Pentacrinoid larva. They cover the mouth and the origin of the ambulacra, just as the orals do in the Neocrinoid; and this relation is not characteristic of the calyx interradials in any Pelmatozoon whatever. It is only in the Cyathocrinidae and in the Blastoids that these plates have any close relation to the mouth at all. But they do not cover it and shut it off completely from the exterior as the summit plates of *Stephanocrinus* and *Allagecrinus* do."

We have been more than once charged by Dr. Carpenter with inaccurate statements as to his views, and in some cases with reason as we have admitted; but we do not believe we have ever been chargeable with anything so completely unfounded as the foregoing criticism. It is based entirely upon the single remark of ours on page 46 (Revision Palaeocr. Pt. III), that "the ventral pyramid in *Haplocrinus* and *Coccocrinus* is composed of interradials and not of orals, and the same may be said of *Stephanocrinus*."* This was written under the supposition, then entertained by all Palaeontologists, perhaps with the exception only of Etheridge and Carpenter, whose interpretation will be quoted presently, that *Stephanocrinus* was constructed of only three ranges of plates, and we considered the third row, constituting the whole portion from the coronal processes inward, to be interradial plates. Messrs. Etheridge and Carpenter[1] in 1883, interpreted all plates, in common with the deltoids of the Blastoids generally, and the interradials of the Cyathocrinidae, as orals,—a view which they have since abandoned. In the same paper—p. 239—they mention five plates in the summit, composing, according to Hall, a central "proboscis," and say that they have "only seen this proboscis in one specimen," and regard it as "a vault of a few pieces covering in the peristome." This shows clearly that they did not themselves at that time consider these

*We even did not use the term "*calyx* interradials" in that quotation, we simply spoke of the "*interradials*."

[1] Ann. and Mag. Nat. Hist. Apr. 1883, pp. 225 to 246.

"proboscis" plates as representing the orals, and, so far as we know, they never afterwards, until the appearance of the Blastoid Catalogue, gave any other interpretation of the inner ring of plates. If they had regarded them as orals, it would have suggested the presence of two rings of orals, the one within the other.

Subsequently we found reason to distinguish two rings above the radials—the so-called orals or deltoids of Etheridge and Carpenter and a series of summit plates—the so-called "proboscis"—from a specimen of *S. gemmiformis;* and we communicated this fact to Dr. Carpenter as early as Dec. 17th 1885 with a diagram explaining it, stating that, although summit plates in our specimen were not preserved, such plates were probably represented in the species. We also informed him that it was the third ring or deltoids, and not the summit plates, which we took to be the homologues of the interradials in *Haplocrinus;* and that the hypothetical plates closing the summit we took to be represented in *Haplocrinus* by the central plate. At the same time we applied to Prof. Whitfield for specimens to ascertain the summit structure in *S. angulatus.* From these specimens we at once found beyond all doubt that the plates of the third row in *S. angulatus,* as well as in *S. gemmiformis,* do not extend to the oral center, but are followed by five other plates—the so-called "proboscis"—covering the mouth (fig. 3). Upon making this discovery we promptly declared the latter to be the orals, and advised Dr. Carpenter accordingly on January 9th 1886. *

Our statement, therefore, that the "ventral pyramid" in *Stephanocrinus* is composed of interradials, was made with reference to plates which we then supposed to be a single element, extending to, but not covering the oral center, and which Etheridge and Carpenter had previously announced to be orals followed by vault pieces, but now consider to be deltoids followed by orals. When the authors assert that we applied the name "calyx interradials" to the "plates which form the ventral pyramid *and cover the mouth of Stephanocrinus* and also of *Haplocrinus,*" we cannot help thinking that they are "going very much too far." A similar erroneous statement was made by Dr. Carpenter in March 1886[1] and it has been a matter of consid-

*It is due to Dr. Carpenter to state here that he had privately communicated to us, after Sect. I of Pt. III of our Revision was in print, that he regarded the inner ring of *Stephanocrinus* as orals, and this led to our correspondence upon the subject.

[1]Ann. and Mag. Nat. Hist., March, 1886, p. 282

erable surprise to us that in both these publications we should be held up to criticism for a statement which we did not make in any such form as their language would imply, and that the authors should indulge in a general adverse comment upon our incidental remark on *Stephanocrinus*, without the slightest intimation of the very important additions to our former views consequent upon new discoveries, which would have made our meaning entirely clear. These were published in Part III, Revision of the Palaeocrinoidea, pp. 282–290.

To represent us as arguing that the plates which we recognize as calyx interradials "cover the actinal center," or "cover the mouth and the origin of the ambulacra," seems to us very much like setting up a man of straw for the pleasure of knocking him down. For our whole argument in favor of a homology of the orals of the Neocrinoid with the central plate in Palaeocrinoids, has been expressly put upon the ground that the latter plate covers the actinal center; and one of the strongest objections we have constantly urged against such a homology with the proximals, has been that they do *not* (Rev. Pal. Pt. III, p. 53). Etheridge and Carpenter add in continuing their criticism above noticed: "There is not a single Crinoid known in which plates which are universally recognized to be calyx interradials cover in the actinal center." Of course not; and we do not know of anybody who says they do. But on the other hand it is equally true that there is not a single Palaeocrinoid known in which the plates that are universally recognized as orals cover the whole ventral surface; and upon this ground we might well contend that if the plates which Etheridge and Carpenter consider to be orals are really such, then *Allagecrinus* and *Haplocrinus* are Neocrinoids, in which from the larva to the adult, as a rule the whole ventral surface is covered by actinal structures. Their statement above cited, as to the homology of plates which "cover the mouth and the origin of the ambulacra, just as the orals do in Neocrinoids," might be profitably applied to the case of *Caryocrinus*, as shown by a number of excellent internal casts recently obtained from Racine, Wisconsin. *Caryocrinus* has a large central piece, and this is surrounded usually by eight plates, which are arranged in a totally different manner from the so-called proximals of the Palaeocrinoidea. Three of them are radial, the others interradial, (figs. 6-7). The interradial pieces alternate with the radial ones, one to each side, except at the anal interradius where three smaller pieces

take the place of the single one at the two other sides. Like most of the Cystidea, *Caryocrinus* has no true radials, although it has well developed arms. The rays start from underneath the central plate in a similar manner as they do in allied genera from underneath their quinque-partite oral pyramid; but the ambulacra, instead of entering the surface at once, as in other groups, here remain subtegminal until they enter the arms, following the medium line of three radial plates, and branch (fig. 7) underneath them twice to their respective arm openings. In this case, the central piece which "covers the mouth and the origin of the ambulacra" must surely represent the orals if any plate does, but not the plates which surround it and cover neither the mouth nor the origin of the ambulacra. We should like to know by what process Messrs. Etheridge and Carpenter will demonstrate the oral nature of either the radial or interradial plates in this form.

We have already alluded to the great importance toward the establishment of Etheridge and Carpenter's oral theory, of their proving the existence both in Crinoids and Blastoids of a summit composed either of five plates only, or of a central plate surrounded by five. This is why the series of parallel transitions or variations in the summit plates of the two groups is so strenuously urged in the Blastoid Catalogue. But it seems to us that the authors have altogether failed to point out a single instance in which five primary plates cover the peristome among the Blastoids. The cases which have been relied upon to prove such a condition, must be attributed to incorrect observation or the want of sufficiently good material. That occasionally in certain species of *Elaeacrinus* the central piece is more or less coalesced with the proximals of the azygous side, and these with one another so as to obscure the suture lines, as we have shown in our illustrations figs. 12 to 14, cannot alter the case in the least, as they are plainly visible in others, and without any change in the general arrangement of the summit. Nor does it seem to us that the authors have been any more successful in showing how among Palaeocrinoids the five large plates in *Haplocrinus*, covering the whole ventral surface except the oral pole, could have been transformed in other groups of the Palaeocrinoidea into six plates covering only a small space around the peristome. These five plates in *Haplocrinus* occupy the same position, as the primary calyx interradials of other groups, and especially resemble those of *Cyathocrinus* and *Stephanocrinus*. (Compare figs. 2 to 5).

It may not be out of place to mention in this connection that in *Haplocrinus* there appear radially between the five large ventral plates, upon their lateral edges, five conspicuous grooves (figs. 4 and 5), which were regarded by Prof. Zittel (Handb. d. Palaeont, I, p. 347) as ambulacral furrows. Similar grooves exist in *Cyathocrinus*, *Stephanocrinus* and other Inadunata along their interradials, and in all of them the grooves are occupied by the ambulacra. The similarity between these grooves, no doubt, induced Prof. Zittel to give to those of *Haplocrinus* the same interpretation. Unfortunately, however, the central plate of *Haplocrinus*, as plainly seen in our specimens, does not occupy exactly the same level as the upper angles of the five large plates, but lies (Fig. 4) below their level and between them, just as if it were being pushed from within outward so as to separate the five plates at the central space. The peculiar position of the central plate demonstrates, we think beyond any doubt, that the ambulacra of *Haplocrinus* could not have been exposed upon this groove, but at the same time it appears to us that these grooves, which occupy relatively the same position toward surrounding plates and the peristome, and are formed in a similar manner, must represent morphologically the same grooves, which are occupied in higher developed types of this group by the ambulacra (fig. 3). Supposing that *Haplocrinus*, as we find it in the fossil state, were but an embryonic stage of the species—the genus has been regarded a permanent larval form of the group—we think we might safely assert from the phylogeny of the Palaeocrinoidea generally, that in the growing animal the central plate was pushed outward so as to appear at a level with the five interradials; that subsequently by the growth of the dorsal cup, and the widening of the peristomial area, proximals appeared around the central piece; and that at last the ambulacra were pushed out to the surface to occupy the radial grooves, which were present already in the young *Haplocrinus*. The different stages to which we here have alluded are well represented in palaeontological times throughout the Inadunata, and not only among them, but also among the Camarata under very similar conditions.

The Camarata or Coadunata differ from the Inadunata in having their proximal arm joints incorporated into the calyx by the upward growth of interradials; while in the Inadunata the arms remain free from the first radial, and they have but one interradial which is disposed ventrally. That all Camarata passed temporarily

in early life through the Inadunata stage, seems to us beyond dispute, and we think we may assert that they were for a time in a similar condition to *Haplocrinus*, with one interradial plate disposed ventrally. Limiting our observations among the Camarata to the Platycrinidae, we find, so far as we know, their simplest forms represented by the two early genera *Culicocrinus* and *Coccocrinus*, which both have two rows of plates interradially disposed, the one resting within the circlet of the other. In *Culicocrinus*,* if Miller's figure is correct, the first row of these plates consists of five rather large pieces, one to each interradius, which connect laterally with the primary and secondary arm plates, so as to make them radials and integral parts of the calyx. Those of the second row which are triangular meet laterally and close the center, apparently without any additional plates.

Of *Coccocrinus* two species are known. *Coccocrinus bacca* has three interradials in the first row, which have a strictly ventral position, *C. rosaceus* apparently but one, which is more erect. In both species the plates extend to the height of the third primary radials, and probably higher. The inner row of plates is only known in *C. rosaceus*, and these, like those of *Culicocrinus*, are subtriangular, but, unlike them, do not connect laterally with one another, nor do they meet in the center. There is a lateral slit between them all the way to the arm openings, and at the center an open space, which in the fossil is not filled by any further structures. In *C. bacca*, as stated, the inner plates have not been preserved, but we scarcely doubt that similar plates were present, for we find in a radial direction between the outer plates of the first row, very conspicuous slits, which correspond to those of *C. rosaceus*.

The outer plates, in the two genera, were regarded by Carpenter as calyx interradials, the inner ones as orals, and these he took to be the homologues of the five large ventral plates of *Haplocrinus*, and of the proximals in other groups.

We admit that *Coccocrinus* and *Culicocrinus* probably are morphologically in a similar condition, and represent early stages in the phylogeny of the Palaeocrinoidea like *Allagecrinus* and *Haplocrinus*,

*Through the kindness of Prof F. Roemer, we received a most excellent gutta percha cast of a *Culicocrinus* with arms, from a mould in the Mineralogical Museum of Breslau, but not showing the ventral covering. Miller's original figures of the ventral covering, Lethea Geognostica of 1855, Taf. VIII, figs. 1 and 2, we are informed are much restored, and the arrangement of the plates, as there given, not altogether reliable.

but we doubt if this is the case in the sense Dr. Carpenter suggests. The two former are Camarata, and as such should be provided with more than one row of interradials, which they would not possess if the inner plates were orals.

Based upon palaeontological evidence, we think, we may reasonably suggest that in the developmental history of *Culicocrinus*, at the close of the Inadunata stage, the first row of interradials opened out to connect the proximal arm plate with the calyx, and that a second ring formed to take the place and functions of the first, closed the center.

Coccocrinus forms a connecting link between *Culicocrinus* and *Platycrinus*. Probably it has one or more summit plates, and the ambulacra disposed between the interradials.

In *Platycrinus*, the inner interradials, which in *Coccocrinus* are yet placed at a level with the dorsal cup, are considerably more raised. In consequence thereof we find in this genus much larger spaces between the interradials, centrally as well as laterally, and hence better developed summit plates and larger and heavier covering pieces. Of the summit pieces probably the central plate appeared at first—this is indicated by the phylogeny of the group—and the proximals appeared later, filling the vacancies, which gradually had formed around the central plate.

In this sketch we have not added anything that is not well sustained by the phylogeny of this group, or is not in accordance with the developmental history of the Palaeocrinoidea generally. Throughout this order, when summit plates are exposed at all, they occupy a comparatively small space around the peristome, and this space increases in width in palaeontological times. In all Palaeocrinoids, so far as known, and we may add, in all Blastoids, the peristomial area is formed by the calyx interradials, whether these consist of one piece, as in the case of the Inadunata and Blastoidea, or of two, three, or a dozen pieces, as in the Camarata; and the summit plates, whether composed of a central plate only, or of proximals also, rest against the upper margin of the interradials. In all Neocrinoidea, however, from the larva to the adult, the whole ventral surface is covered by actinal structures, the small interradials which were observed by Sir Wyville Thomson, disappear again soon after their development, and never attain any such prominence in the composition of the calyx as in the earlier Crinoids. This character, which distinguishes the two groups so readily, would meet with most

serious exceptions if the ventral plates in *Allagecrinus, Haplocrinus, Culicocrinus* and *Coccocrinus*, as asserted by Carpenter, represented the orals. We think it was the superficial resemblance in the form and position of these plates with the orals of certain Neocrinoidea that led Carpenter to regard them as orals. He probably overlooked the fact that the plates agree equally well on those points with the interradials of the Cyathocrinidae, and that as interradials the above genera would not be exceptional types, but comply with the morphological conditions of all their contemporaries.

We have shown that *Culicocrinus* and *Coccocrinus*, as members of the Camarata, should have more than one interradial plate, and it is not very likely that the secondary one, exceptionally in those genera, would be substituted by a ring of oral plates. But there is another serious difficulty. The slits in *C. bacca* extend out to the first row of ventral plates as well as to the second, and this suggests that, if *Coccocrinus* were "like the recent genus *Holopus*" to be "permanently in the condition of a crinoid larva, in which the orals have not yet moved away from the radials, though separated from one another,"* then both rows of plates were orals, one ring within the other. Where among the numerous families of the Palaeocrinoidea do we find an instance in which the plates constituting either the oral pyramid or the proximals, are separated in that manner? Nowhere; but if there was such a case, we certainly would find it in the highest developed forms and not in the larval ones. Again, where do we meet among Palaeocrinoids with an open peristome? In the earliest stages of the Neocrinoid larva, the orals are closed, and in the earlier forms of the Camarata, such as *Reteocrinus, Glyptocrinus*, etc., the peristome is closed either by the upward growth of the calyx, or by a small central piece, there being no proximals, and hence, according to Carpenter's interpretation of these plates, no orals. Those genera appear to us to be in a similar condition to *Allagecrinus* and *Haplocrinus* among the Inadunata, and *Culicocrinus* and *Coccocrinus* among the Camarata, but not in the condition of the Neocrinoidea at all. However, we can readily understand why Carpenter holds so tenaciously to these plates as orals, for it is principally upon these plates that he bases his further theory, that in the higher Palaeocrinoidea the orals are represented by the proximals; indeed they are his "simplest forms" which he failed to find among Blastoids. In the Challenger Report on p. 170, he says: "The proximal dome

* Chall. Report, p. 163.

plates rest directly against the calyx interradials, that on the posterior side being represented by two small plates with the anus between them" while there is a more or less tubercular ring of radial dome plates outside them. These proximal dome plates thus correspond exactly to the orals of *Symbathocrinus* and *Haplocrinus*, covering in the peristome and resting against the calyx plates, which in the *Platycrinus* are the interradials, and not the upper edges of the radials, as in the simpler forms"; and on p. 171: "I cannot therefore see what other view can be taken of the proximal dome plates which immediately surround the orocentral, than to regard them as orals, *i. e.*, as the actinal representatives of the basals, like the corresponding plates in *Symbathocrinus*. *If this be admitted*, it follows that the proximal dome plates of all Platycrinidae, Actinocrinidae and Rhodocrinidae are also homologous with the orals of Neocrinoids."

These conclusions *perhaps* might be well enough, IF such a thing as an orocentral had been established; but unfortunately this is not the case. Neither are the plates in *Symbathocrinus* of which he speaks as "the orals," in our opinion, anything but proximals, and hence all conclusions based thereon, to say the least of it, are inexpedient and rash. It is somewhat surprising that Dr. Carpenter, although his whole theory is actually based upon his hypothetical "orocentral," gives such a meagre account of it. In the Challenger Report, in introducing it on p. 158, he devotes to it only a few lines. Referring to the small central plate of *Haplocrinus*, he says: "This plate is one of considerable importance in its morphological relations. In accordance with the views which I have expressed elsewhere, I believe it to be the representative on the actinal side, or left larval antimer, of the dorsocentral plate which is developed in the center of the right antimer or abactinal side of Urchins, Stellerids, and Crinoids." And on pp. 159 and 170, in pointing out its relations to the proximals, he calls the plate the orocentral, and speaks of it as a single plate. That is all Dr. Carpenter had to say about it, and probably all that could be said, for such a plate has been heretofore unknown in Echinoderm morphology.

We do not deny that the so called dorsocentral of Urchins and Stellerids is represented in the Comatula larva by the terminal plate of the stem, but we see no good reason to postulate from this a similar plate in the oral center. There are at the abactinal side frequently also underbasals, which on the same principle should be represented orally, but nothing is known of them. Why should

the dorsocentral be represented at the actinal side when there is no actinal stem, in this or any other group of the Echinoderms? The dorsocentral in the Echinozoa represents in a wider sense the whole column in its simplest form, although in a narrower sense it is the homologue of the first part of the stem that makes its appearance in the embryo. If there was such a thing as an orocentral in fossil Crinoids, Blastoids and Cystids, it seems to us, it certainly would be represented in the early larva of the living types before the parting of the orals, and in the closed oral pyramid of the Cystids and *Stephanocrinus*; but unfortunately for Carpenter's theory we meet with no trace of it in either one of those forms. The plate which he regards as orocentral, occupies the place of the five orals in other groups, and in a similar manner as these, covers the peristome and the origin of the ambulacra. This is conclusively shown by comparing the case of *Caryocrinus* in which the ambulacra start from beneath the central plate and branch twice underneath the surrounding plates, with the case of *Sphaeronites* (fig. 1) and *Stephanocrinus* (fig. 3), in which the ambulacra start from beneath a penta-partite oral pyramid. Does this indicate that the five plates constituting the latter, are the representatives of the proximals? We doubt it, for the structural resemblance is with the central piece. We think the distribution and arrangement of the surrounding plates in *Caryocrinus* proves conclusively that these cannot be orals, for the most ingenious speculator would be unable to reconstruct five primitive plates from such an assemblage of pieces as we find in *Caryocrinus* and in Von Koenen's new genus *Juglandocrinus**. What those plates may be, whether actinal or abactinal structures, we will not pretend to decide, but we do undertake to say that they are not orals, otherwise the rule that there are always five primitive orals meets with a very serious exception.

Somewhat more favorable perhaps to Carpenter's views is the arrangement of the proximals in the Palaeocrinoidea and Blastoidea, in which the plates surrounding the central piece are unquestionably actinal structures, and there is a possibility of reconstructing from the six, seven, or more pieces, five primitive plates. We also admit that in all cases where those plates come in direct contact with the anal structures, their arrangement might possibly have been disturbed thereby, but this explanation is not applicable to forms like *Megistocrinus*, *Dorycrinus* and many others, in which the anus is lateral or moved away from the center to the arm regions or even beneath them. But there are several other equally serious objections.

*Neues Jahrbuch fur Mineralogie 1886, Bd. II, Taf. IX, Fig. 3.

In the Comatula larva, which shows a decidedly bilateral symmetry, there are five equal basals and five equal orals. In *Thaumatocrinus*, although it has anal plates and a large proboscis, the basals and anals remain undisturbed. The same may be said of the basals of the Palaeocrinoidea and Blastoidea; among which not a single instance is known where the basal ring contains either anals or radials, contrary to the proximals, among which nearly always anals and often radials are enclosed. This shows that the presence of such plates, if the proximals in those groups represent the orals, and the latter the basals, would be totally at variance with the general rules of the class both as to orals and basals.

The anal plates of the apical side either abut directly against the radials, or are placed between the interradials. In most of the Camarata, the first interradial at the azygous side is split into two halves by the first or second anal piece. In others, the second anal is wanting, but the interradial is composed of two parts as if the anal were present. In a few groups there are no anal plates whatever, and the arrangement of the plates at all five sides is alike.

The same variations as among the interradials are found in the arrangement of the proximals,* of which the four large plates correspond to the calyx interradials at the four regular sides. The two smaller proximals, which occupy the azygous interradius, either are placed between two radial dome plates or they abut against two of the larger proximals, enclosing generally an anal plate—but this may be absent or pushed downard.

As yet, we have not observed a single instance in which there were five plates around a central one, but should it occur, which we think is very possible, we doubt if Messrs. Etheridge and Carpenter, although finding at last their "simpler form," will be able to make much out of it in support of their theories.

We stated heretofore that fig. A on p. 72 of the Blast. Cat. is erroneous, and this, to some extent is the case with fig. B on the same page. We never saw a *Platycrinus* with a single interradial, all having three (or more), arranged transversely. Besides, the figure is misleading in not giving the central piece and the so-called radial-dome plates. If these plates had been added, as they should have been to represent the case properly, it would show that the radial-dome plates are placed opposite the radials, the proximals opposite the interradials, and that the central piece takes orally the

*For the arrangement of the proximals see Revision Pt. III, pp. 47 to 50.

position of the coalesced basal disc; a totally different thing from what the English authors attempted to prove by their figure.

We are altogether in accord with Goette and Carpenter in their opinion that the orals are represented in the abactinal system by the basals, but we disagree entirely with the latter writer that the basals are represented orally by the proximals. We regard the proximals as an element similar to the interradials, but, while these fill up vacancies in the calyx, the former fill the open space around the peristome as it widens in the growing animal by the increasing width of the dorsal cup. To this conclusion we were led principally by the arrangement of the plates, the presence of radial and anal plates in the same ring with them, and by their gradual appearance in geological times. We further believe the central piece is the only plate which in the Palaeocrinoidea and Blastoidea can possibly represent the quinque-partite oral pyramid. We regard it as being primitively composed of five pieces, such as remained intact persistently in *Stephanocrinus* and most of the Cystidea, but which were fused together by anchylosis in other groups as aborally in the case of the basals, which gradually were reduced from five to three, and in certain groups to one solid piece. The proximals, therefore, in our opinion, are not of that morphological importance as they are regarded by Dr. Carpenter, and we think the same may be said of the so-called radial dome plates. These also, like the proximals, seem to us mere auxiliary pieces, filling up vacancies, beneath which the branching of the ambulacra takes place. If they deserve the term radials at all, they certainly represent the axillaries, and not the oculars or first radials, except perhaps in some very complex species in which there appear three successive pieces to each ray, the inner ones resting against the central plate in a similar manner as the true radials rest against the basals; while the third or axillary one holds toward the proximals and the ambulacra the very same relations as the single radial does in the simpler form (See Revision Pt. III, Pl. IV, Fig. 4, and Pl. VIII, Figs. 1, 3.). It is also very significant that frequently in those complex forms there appear toward the center *within the ring of proximals* (orals of Ether. and Carp.), two extra axillaries underneath which the two lateral rays, which are united close to the peristome, divide so as to form the antero-and postero- lateral rays. How Dr. Carpenter will explain the presence of these plates within the "oral" ring, which is said to cover the origin of the ambulacra, is a mystery to us, and we look to him for in-

formation. The radial dome plates, as a rule, disappear when the ambulacra enter the surface, and this explains why they are absent in Blastoids,* *Stephanocrinus* and the later Cyathocrinidae.

We have already alluded to the fact that the proximals are frequently unrepresented in the earlier groups, in which, as a rule, the peristomial area is comparatively smaller than in later ones, and closed only by a small central piece. Upon this point it is very interesting that we have recently discovered the same thing in later groups under somewhat different conditions. In two cases, the one a species of *Talarocrinus* from the St. Louis group of Kentucky (Fig. 10), the other a *Dichocrinus* from the Kinderhook of Iowa, we found the whole space usually occupied by central piece and proximals, although as large as in any *Platycrinus*, filled completely by an enormous, nodose central plate, with the covering pieces abutting against it. Interposed between the ambulacra are a number of small interradial plates, which barely touch the central piece. In these cases, according to our interpretation, the increasing space of the peristomial area was filled by lateral growth of the orals (central piece), instead of by means of proximals. But according to Carpenter's generalizations (Challenger Report, p. 171), the insignificant interradials next to the central piece, and between the ambulacra, should be the representatives of the orals or else his rules would encounter another serious objection.

Dr. Carpenter regards both *Allagecrinus* and *Haplocrinus* as representing in a phylogenetic sense embryonic stages of the Palaeocrinoidea. If this be true, he has failed to give a reasonable explanation how the large plates covering almost the whole ventral side in these low forms, came to be placed in this group so as to occupy only the relatively small space they do in what he regards as higher developed forms. Etheridge and Carpenter undertook to prove it in their paper, Annals and Mag. Nat. Hist., Apr. 1881, p. 289, by imagining that, in the more mature specimens of *Allagecrinus* "the orals were relatively carried inwards, away from the radials, and separated from them by perisome (just as they are in the Pentacrinoid larva of Comatula) when the arms appear above the radials. Whether the orals ever separated so as to open the mouth to the exterior, and whether the ring of perisome forming the ventral disk

* Etheridge and Carpenter figure, Blastoid Catalogue on Pl. XVIII, Fig, 16, *Elaeacrinus Verneuili* with radial dome plates; none of our specimens show any traces of them.

between them and the radials was naked, as in *Rhizocrinus*, or plated, as in *Hyocrinus*, must of course remain undiscovered."

This explanation is suggestive enough of what may occur in the Neocrinoidea, but they fail to give a parallel case in which such a development as this took place in a single Palaeocrinoid, and this omission is the more important since they place the genus *Allagecrinus* in the latter group. They state afterwards (op. cit. p. 289). "It is true we have no proof that there were any orals at all in the older specimens; but, judging from the relative sizes and development of the largest examples with oral plates, and the smallest without, we think it scarcely likely that they were entirely unrepresented in the adult. It is obvious that, if they were united to the radials by perisome, whether plated or bare, they would be readily lost under conditions that would have had no destructive effect on younger specimens, in which there was a closer union between the two rings of plates."

From the foregoing quotation, it is obvious that the Authors desired to prove from the fact that the ventral plates were not found preserved in what they regarded as the most mature stages of the species, that they could not have rested upon the radials as in their younger examples, and that they were parted from the radials by perisome. Upon this proposition we will observe that we have never found among Palaeocrinoids the slightest evidence indicating to us that any of the summit plates were carried inward by perisome. We find that among the Camarata they occupy a comparatively small space, but larger than in the Blastoidea, and that in all cases in which they occur, they are supported by the upward growth of the interradials. In the simpler forms of the Inadunata, when observed, they rest upon a single interradial plate as in the case of the Silurian *Cyathocrinus alutaceous* (Ang.). In the Carboniferous form of *Cyathocrinus*, in which the ambulacra are placed upon the lateral edges of the interradials, the orals are not carried inward by perisome, but the perisome appears upon the surface of the interradial plates. That the ventral plates were not preserved in the so-called adult specimens of *Allagecrinus* is no proof that they did not exist, or that they were carried inward. The simple fact that the radials underwent the change from the horse-shoe form to a higher state of development, having strongly marked articular facets, extending to the whole width of the plates, is sufficient to explain why the interradials were not intact or reduced in the adult stages. We

need only refer to the parallel cases of Cyathocrinidae and Poteriocrinidae. In the former, in which the articular facets were comparatively undeveloped, we have been able, in a number of instances, to observe ventrally the interradial plates, which Etheridge and Carpenter formerly regarded as structually identical with the so-called orals of *Allagecrinus*. While in the Poteriocrinidae, in which the articular facets are highly developed, no trace of these plates has ever been found.

We, of course, do not claim that this is positive proof, that in *Allagecrinus* these plates were not carried inward by perisome, but it militates strongly against the probability of such a thing, while the theory that they were is at best but the merest conjecture. If Etheridge and Carpenter had placed *Allagecrinus* and *Haplocrinus* among the Neocrinoidea as larval forms, they might be much better warranted in supposing that the plates in question were orals, and were afterwards carried inward, but both forms have been referred by them to the Palaeocrinoidea, in which that mode of development is altogether unknown. The case of *Cyathocrinus* shows clearly that in the later types of the Inadunata the conditions of the Palaeocrinoidea remain unchanged. The summit plates are not carried inward by perisome, but occupy the same space as in the earlier forms, and the perisome is formed upon the outer surface of the interradials. (Revision, Pt. III, Pl. IV, Figs, 2, 3, 6.)

We should like to know upon what ground the authors maintain that those genera are Palaeocrinoids, when they interpret their structures according to the rules characteristic of the Neocrinoidea. They neither have an anal plate, nor does *Allagecrinus* show any such irregularity in the arrangement of its plates, as would of itself warrant a reference to the Palaeocrinoids. The only irregularity noticed in *Allagecrinus* is that the radials in some specimens may be axillary in one to four of the rays, or not axillary in any of them, and upon this character, curiously enough, Etheridge and Carpenter seem to have separated *Allagecrinus* from the Haplocrinidae and made it the type of a distinct family. On this alone it appears they divide it from the Neocrinoidea, as if it were one of the most constant characters among the Palaeocrinoids; while in fact this peculiarity is found only in the Catillocrinidae, in two of the rays of *Tribrachiocrinus*, and occasionally in *Allagecrinus*. A character like this is liable to be discovered exceptionally in any new form of Neocrinoids, just as well as among Palaeocrinoids, while among

the latter we find a number of genera, in which the arrangement of of the dorsal cup is altogether symmetrical.

It will not, of course, be inferred from the foregoing remarks that we think *Allagecrinus* and *Haplocrinus* belong to the Neocrinoidea, but simply that, if Messrs. Etheridge and Carpenter's arguments are valid, they necessarily lead to that conclusion. We think, on the contrary, there are the strongest reasons for considering them both to be Palaeocrinoids, and that there is no difficulty in discovering entire conformity in their morphological conditions with other Palaeocrinoids.

Whatever arguments Messrs. Etheridge and Carpenter may hereafter offer in favor of their oral theory, it seems to us, they will have to explain upon palaeontological grounds how the five large ventral plates of *Allagecrinus* and *Haplocrinus* which cover the *whole ventral surface* happen to occupy in all higher or more advanced forms a comparatively *small space* around the peristome. They will have to point out by what process the *five* plates, without coming in contact with the anus, were transformed into *six* pieces *or more;* and they will have to furnish better proof as to the existence of a so-called "orocentral," or they will have to modify their generalizations, which are based almost exclusively upon this highly hypothetical plate.

Explanations of Figures, Plate IV.

(The following letters are employed throughout the figures).

o, Oral plate or oral pyramid; p, proximals; i, interradials; ia, interaxillaries; r, radials; a, anal plate; x, anus, g, grooves.

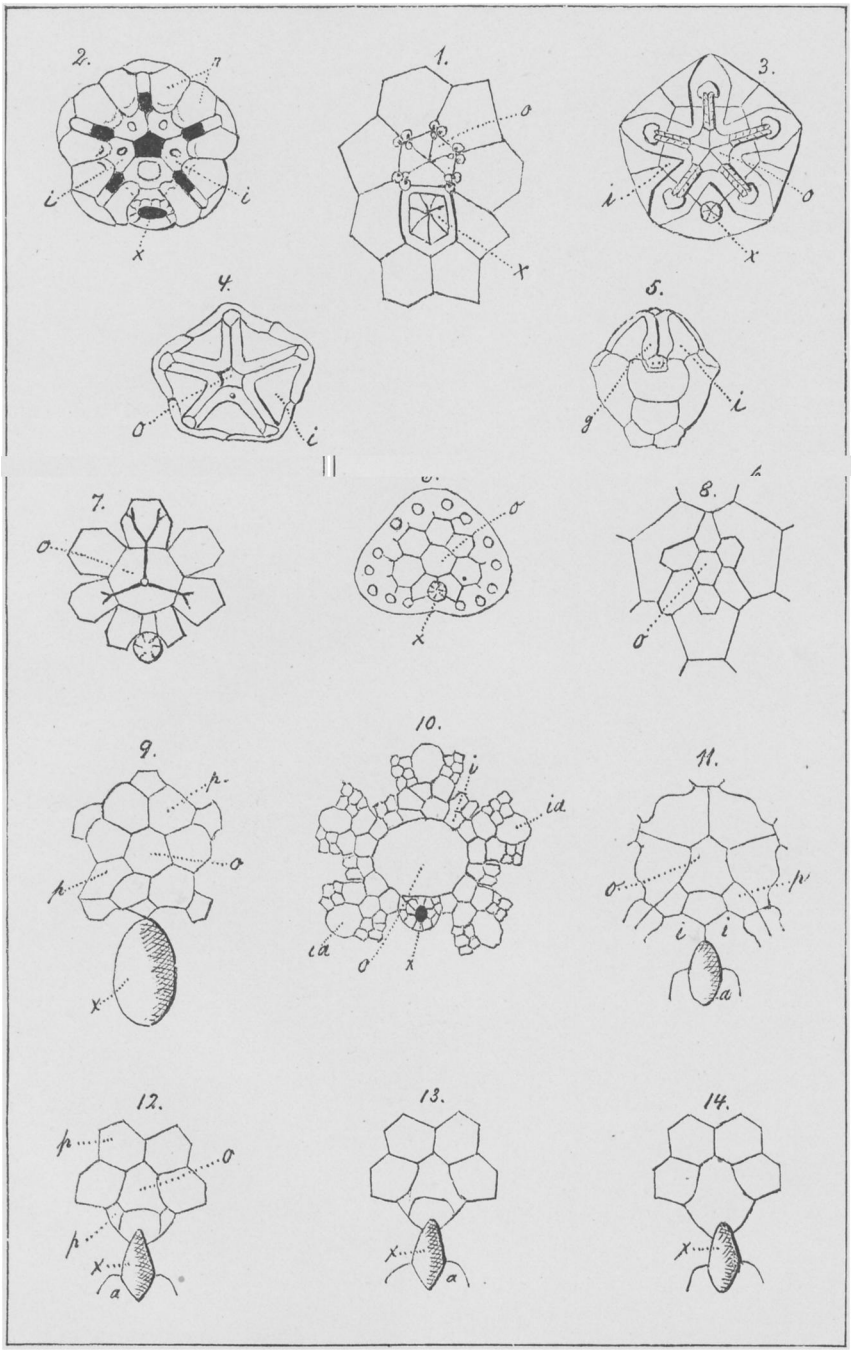
Fig. 1. Oral pyramid and surrounding plates of *Sphaeronites globosus* (after Angelin, Icon. Crin. Suec. Tab. XI, Fig. 14.)

2. Ventral aspect of *Cyathocrinus Gilesi.*
3. The same of *Stephanocrinus angulatus.*
4. The same of *Haplocrinus mespiliformis.*
5. Profile view of the same species.
6. Ventral aspect of *Caryocrinus ornatus* (after Hall, Palaeont. N. York, Vol. II, Pl. 41a, Fig. 1e).
7. The ventral plates of *Caryocrinus* from near Louisville, Ky. (The course of the subtegminal ambulacral tubes indicated upon the surface of the plates).
8. The same of *Juglandocrinus crassus* (after von Koenen, Jahrb. Miner. Bd. II, Taf. IX, Fig. 3.).
9. Ventral covering of a new *Talarocrinus* from Kentucky; the peristomial area closed by a large central plate without the aid of proximals.

10. The summit plates of *Elaeacrinus Verneuili* (after Eth. and Carp., Blast. Catal. Pl. XVIII, Fig. 16).

11. The same of *Elaeacrinus elegans* (from Hall's type in the National Museum of New York.)

12–14. The same of *Elaeacrinus obovatus*, as seen in different specimens. Fig. 12, all the sutures visible. Fig. 13, the suture between central piece and smaller proximals obliterated. Fig. 14, also those toward the small anal plate obliterated.



WACHSMUTH & SPRINGER, SUMMIT PLATES OF BLASTOIDS ETC.